Snowmass 2013
@Mississippi 1, 2013

Hyper-Kamiokande -status of project-

T. Nakaya (Kyoto)
for the Hyper-K working group

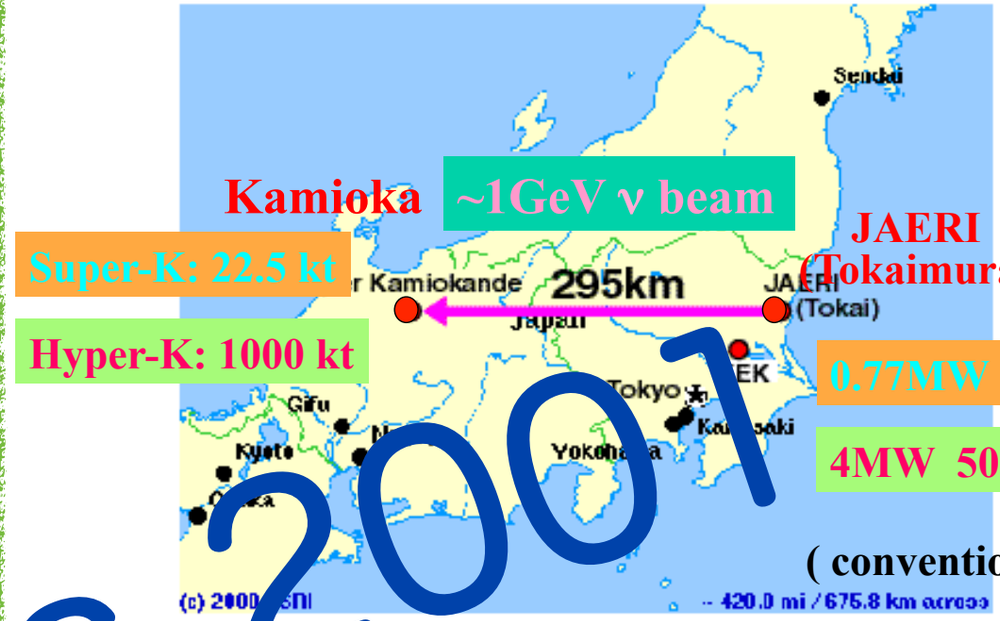
July 13, 2001
@SNOWMASS

The JHF-Kamioka Neutrino experiment

Tsuyoshi NAKAYA (Kyoto U.)
for JHF-SK working group

1. Introduction
2. Neutrino beam & detector
3. Physics sensitivity in Phase-I
4. Physics sensitivity in Phase-II
5. Summary and Conclusi

2.Neutrino beam and detector

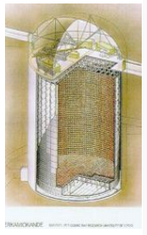


Phase-I (0.77MW + Super-K)
Phase-II (4MW+Hyper-K) ~ Phase-I × 200

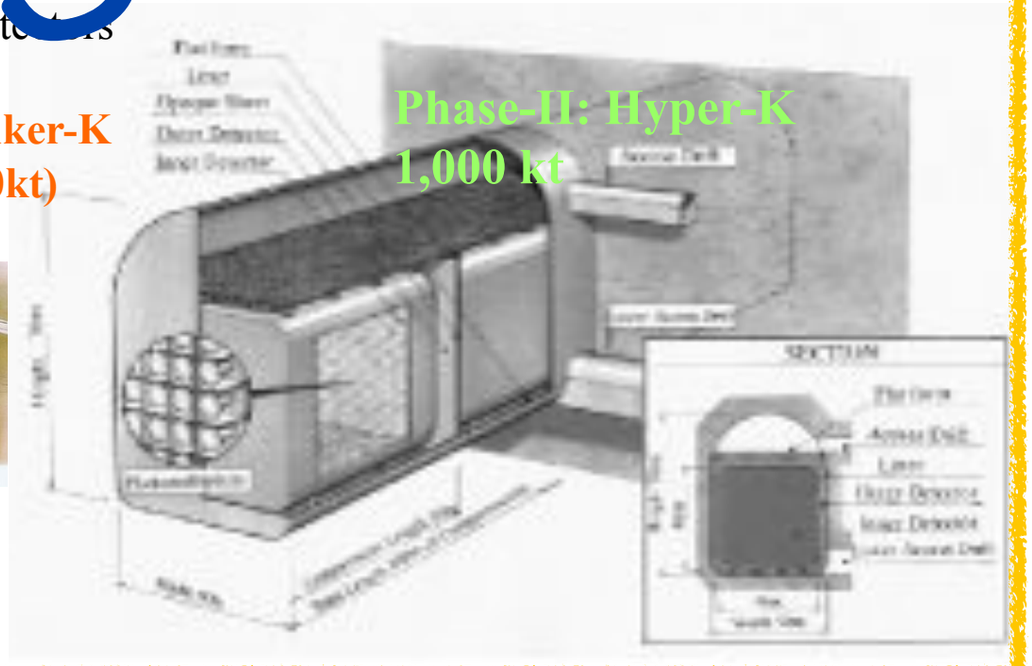
ν detector

- Near ν detector: under R&D (join JHF-SK nu workshop)
- Far ν detectors

Phase-I: Suker-K
22.5kt (50kt)



Phase-II: Hyper-K
1,000 kt

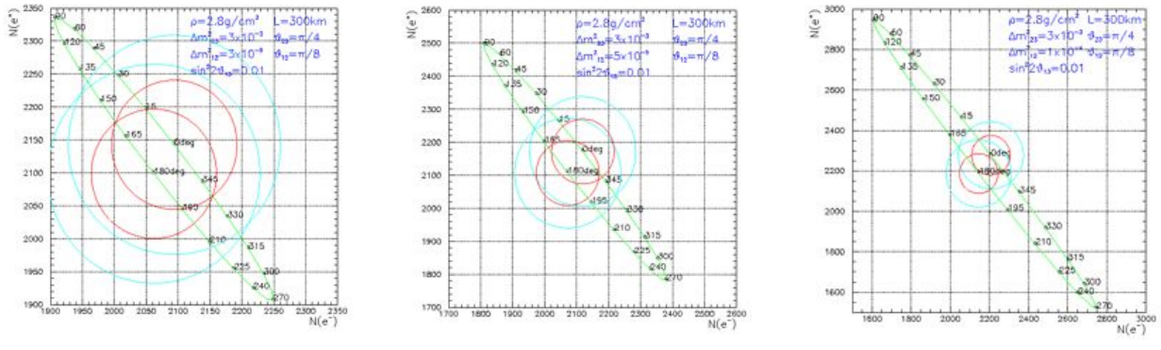


θ_{13}, Δm_{12} dependence for CP sensitivity

$$A_{CP} \propto \Delta m_{12}^{\ 2} / \sin^2 2\theta_{13}$$

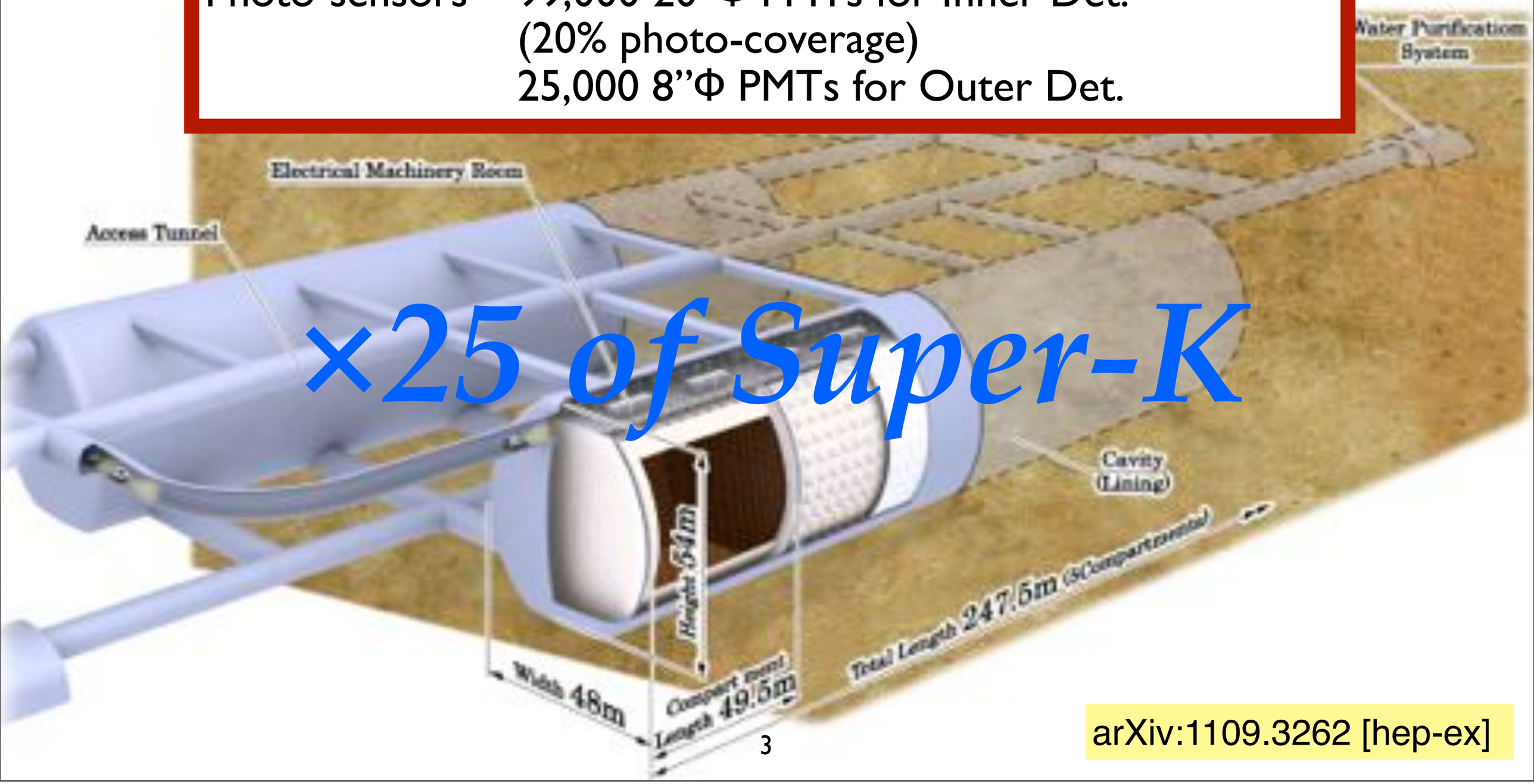
- **NO** θ_{13} dependence for $\sin^2 2\theta_{13} > 0.01$
  - For $\sin^2 2\theta_{13} < 0.01$, there is an effect of background
- Δm_{12}^2 dependence ($\Delta m_{12}^2 > 2\sim3\cdot10^{-5}\mathrm{eV}^2$)

$\Delta m_{12}^2 = 3\cdot10^{-5}\mathrm{eV}^2$ | $\Delta m_{12}^2 = 5\cdot10^{-5}\mathrm{eV}^2$ | $\Delta m_{12}^2 = 10\cdot10^{-5}\mathrm{eV}^2$



Hyper-K Overview

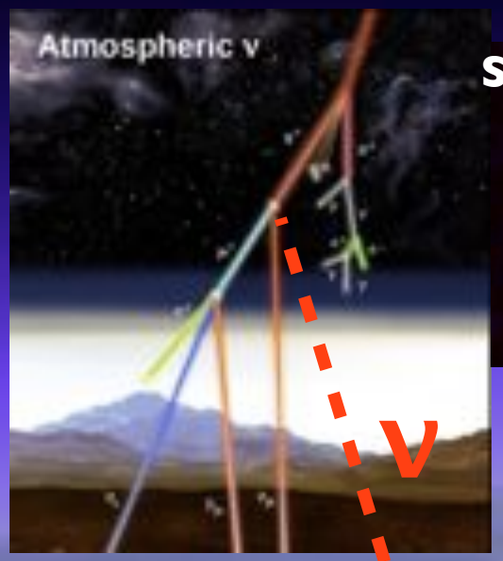
Total Volume	0.99 Megaton
Inner Volume	0.74 Mton
Fiducial Volume	0.56 Mton (0.056 Mton × 10 compartments)
Outer Volume	0.2 Megaton
Photo-sensors	99,000 20”Φ PMTs for Inner Det. (20% photo-coverage) 25,000 8”Φ PMTs for Outer Det.

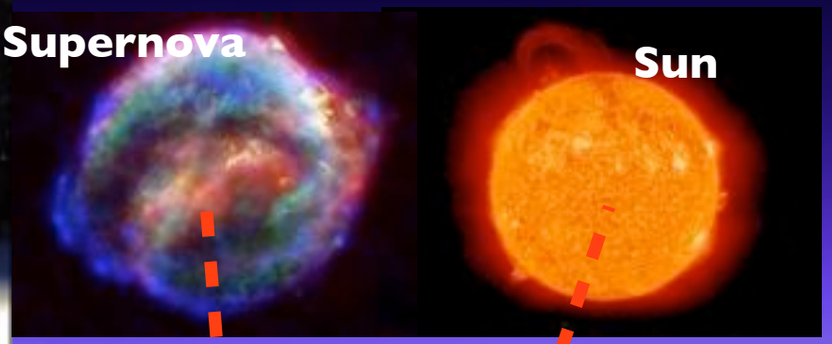


×25 of Super-K

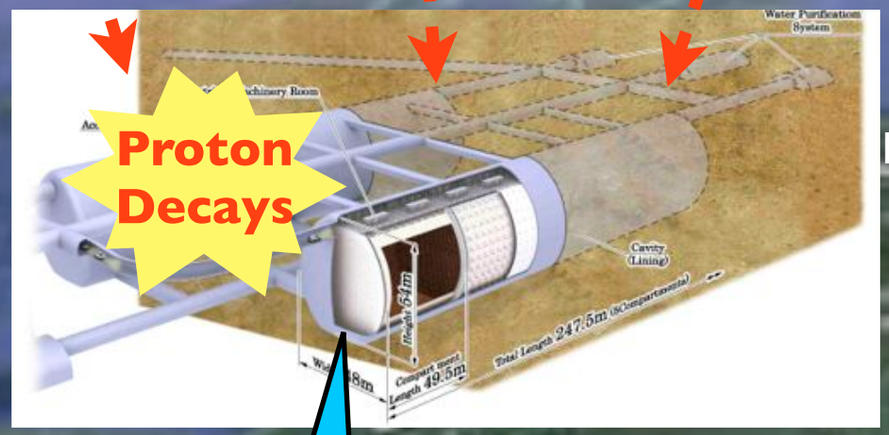
arXiv:1109.3262 [hep-ex]

x50 for νCP to T2K





ν ν ν



Hyper-K

ν

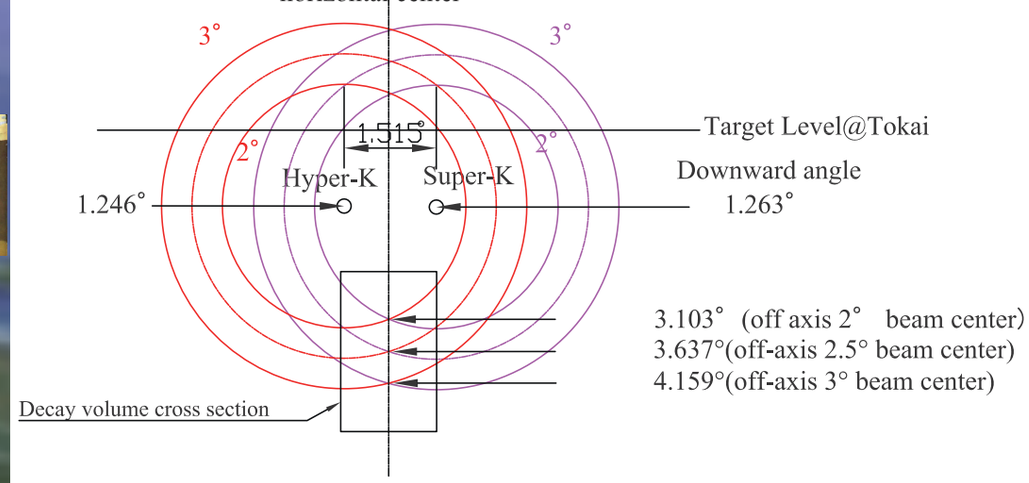


Fig. 13. Schematic directional view of Super-K and Hyper-K from the neutrino beam line target at J-PARC.

x25 Larger ν Target
& Proton Decay Source

higher intensity ν by
upgraded J-PARC

x2 (year
or power)

International Hyper-K meetings

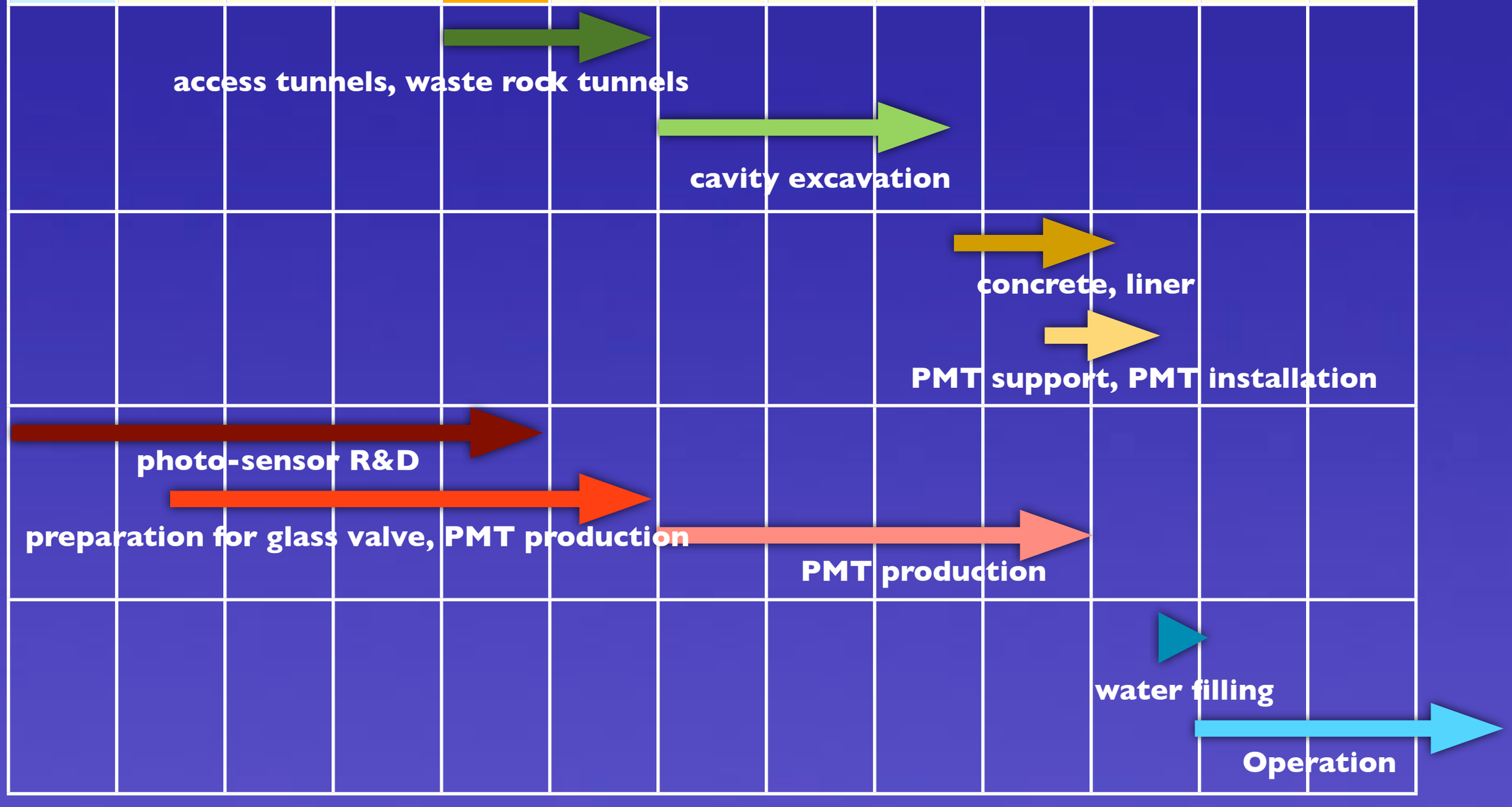
- Open to the international community.
- International Working groups formed are very active.

- Next meeting: Jan. 27-28, 2014 @ Kavli IPMU, Kashiwa, JAPAN
  - Three meetings so far:
    - Aug. 2012 (1st), Jan.2013 (2nd), Jun. 2013 (3rd)
    - http://indico.ipmu.jp/indico/conferenceDisplay.py?ovw=True&confId=23

Target Schedule

Construction start

JFY2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
-4	-3	-2	-1	1	2	3	4	5	6	7	8	9

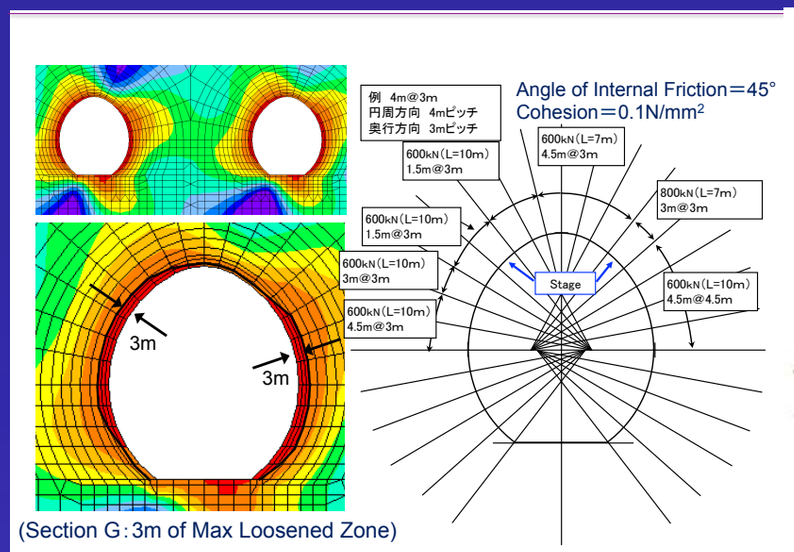


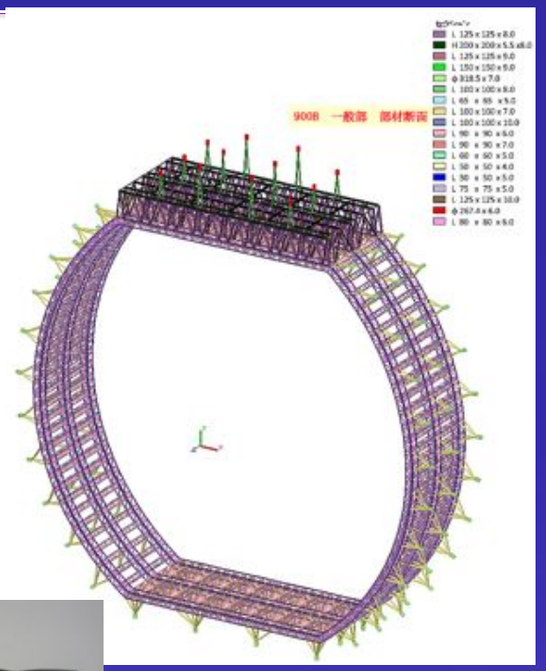
assuming budget being approved from JFY2016

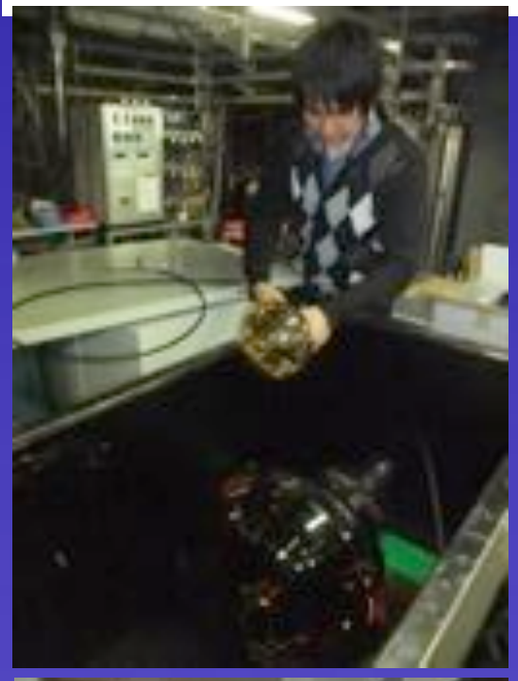
Many R&D going

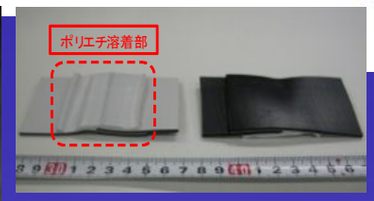
Development works

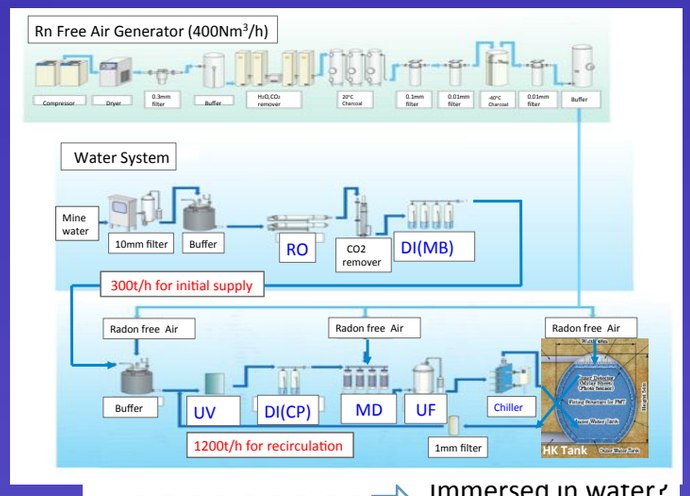
- Detector design optimization
  - tank shape, segmentation wall, tank liner, PMT support structure
- Water purification system, water quality control
- DAQ electronics (under water?)
- Calibration source deployment system
  - automated, 3D control
- Software development
  - Detector geometry optimization, enhance physics capabilities
- Physics potential studies
  - requirements for near detectors
- works in the international working group

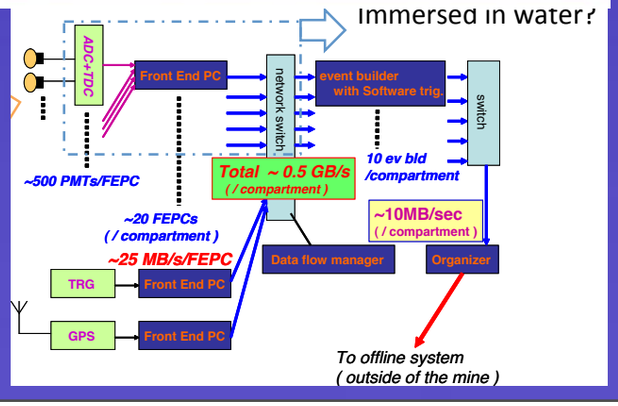






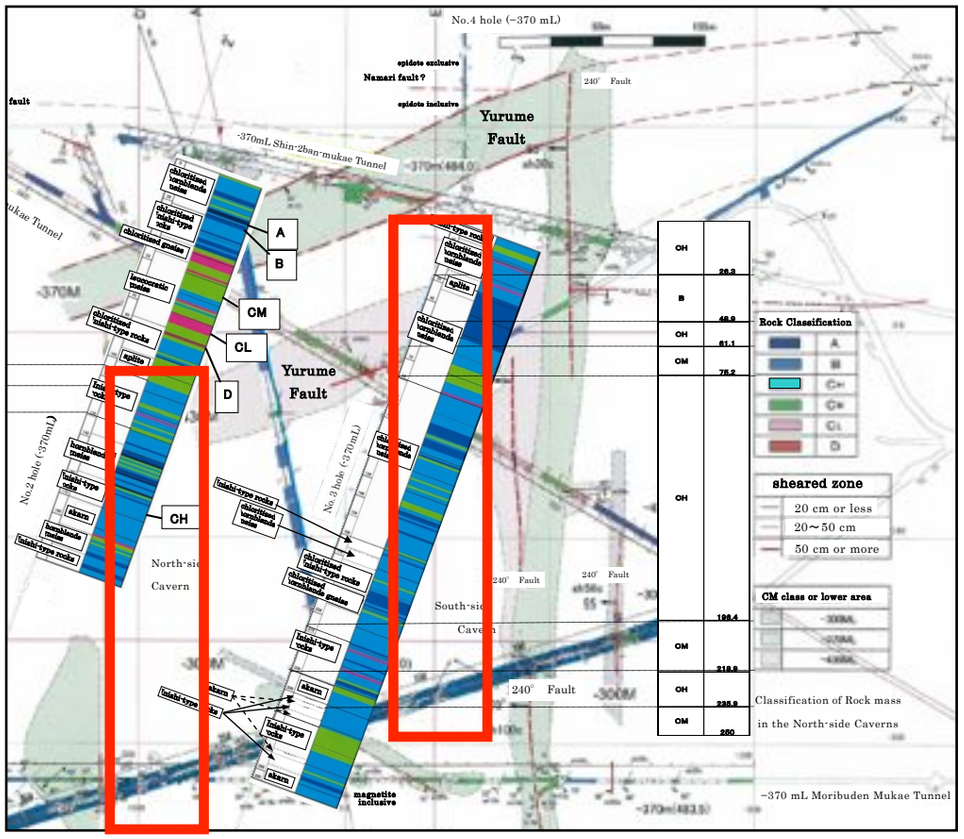






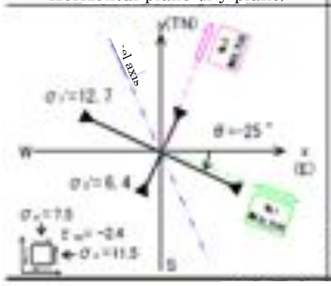
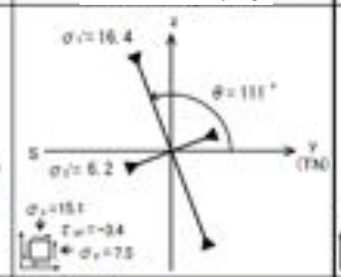
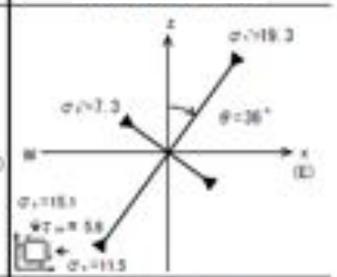
Geological survey & Cavern stability

Rock mass characterization

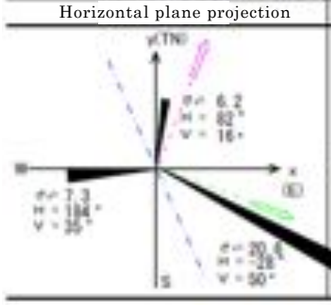
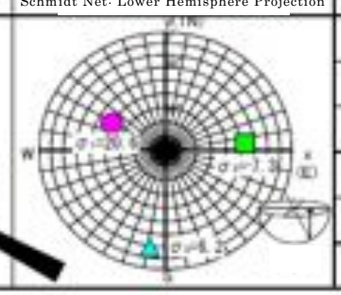


Initial stress (in-situ meas.)

In-plane principal stress (MPa)

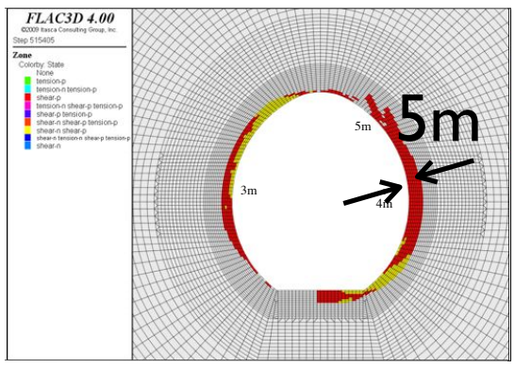
Horizontal plane (x-y plane)	North-south section (y-z plane)	East-west section (z-x plane)
		

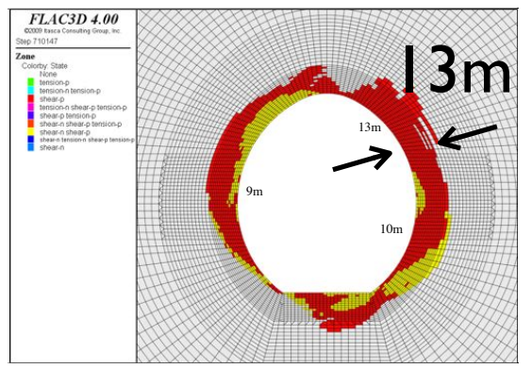
3D principal stress (MPa)

Horizontal plane projection	Schmidt Net: Lower Hemisphere Projection	Six Stress Components (MPa)	
		σ_x	11.5
		σ_y	7.5
		σ_z	15.1
		τ_{xy}	-2.4
		τ_{yz}	-3.4
		τ_{zx}	5.8

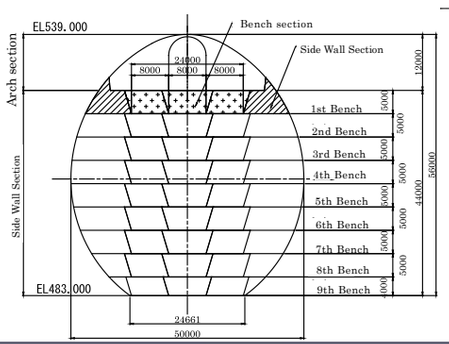
- Detailed geological surveys at the candidates site vicinity
- Cavern stability and its supporting method has been studied
- Confirmed that the HK cavern can be constructed with the existing techniques

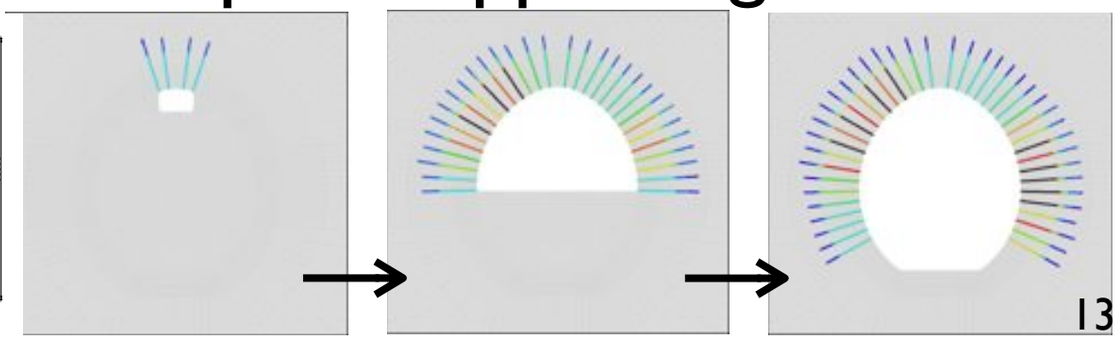
Cavern stability



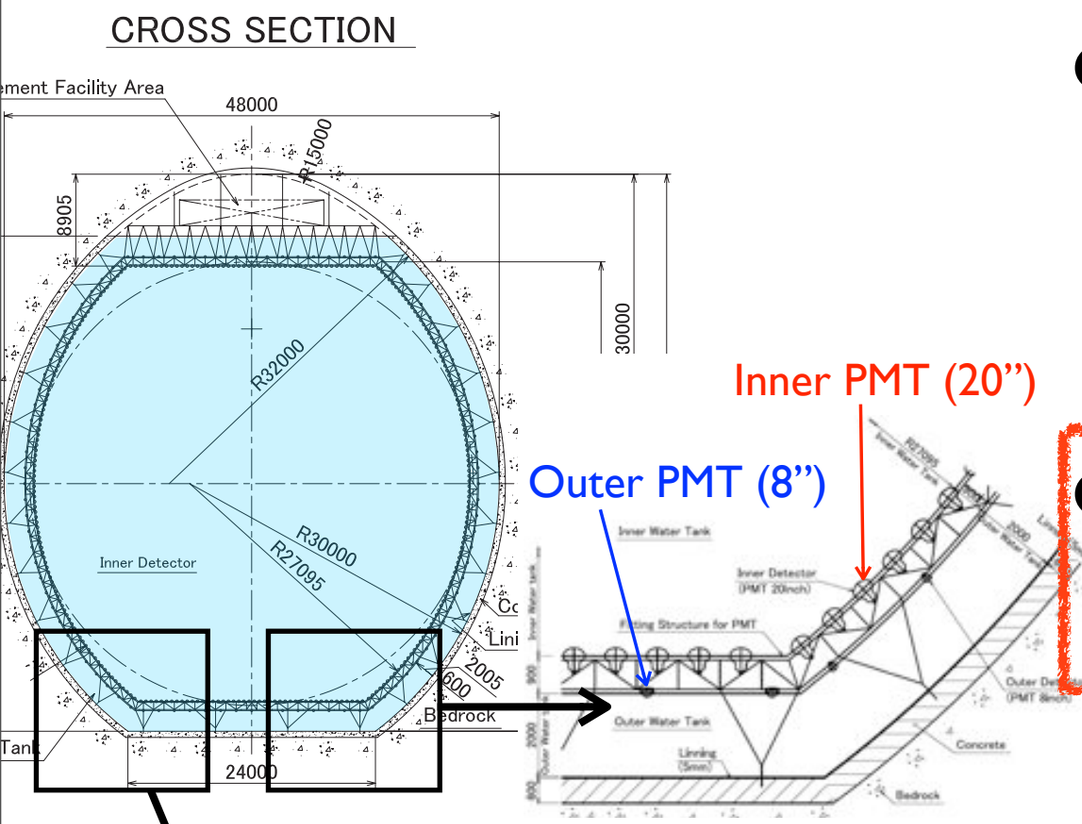


Excavation steps & supporting method



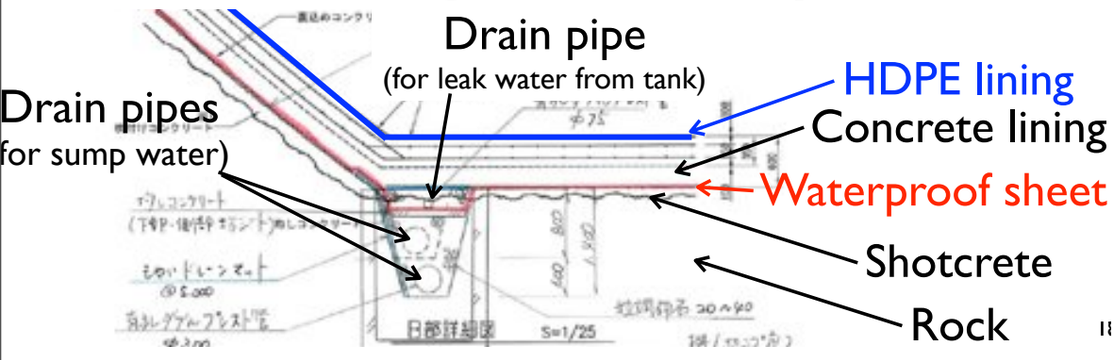


Tank and photo-sensor support



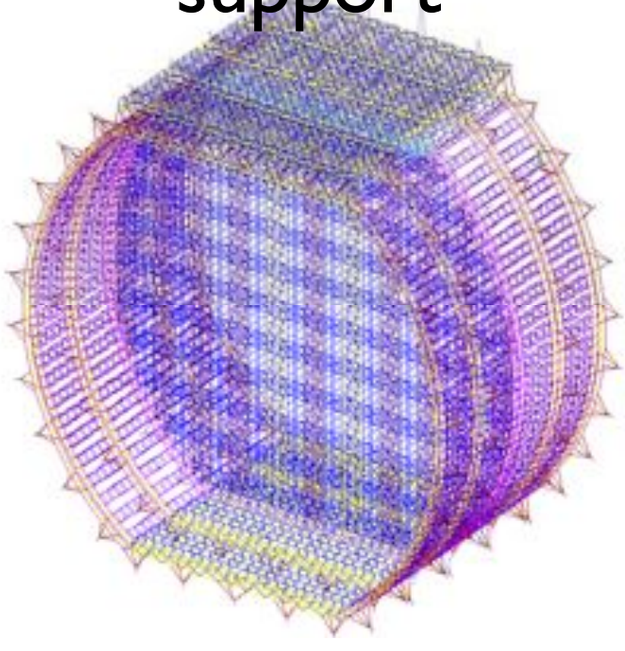
- Baseline designs of the water containment system and photo-sensor support are ready
- Build a prototype detector (1kt)
  - Funding request approved

Lining & drain system

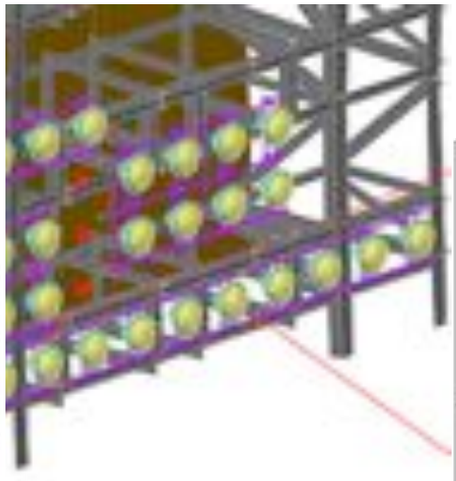


Polyethylene sheet

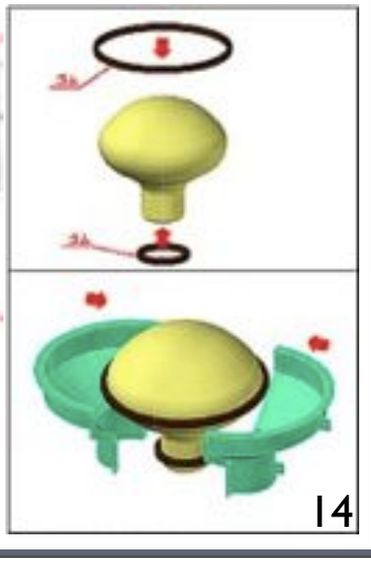
Photo-sensor support



Mounting Photo-sensor

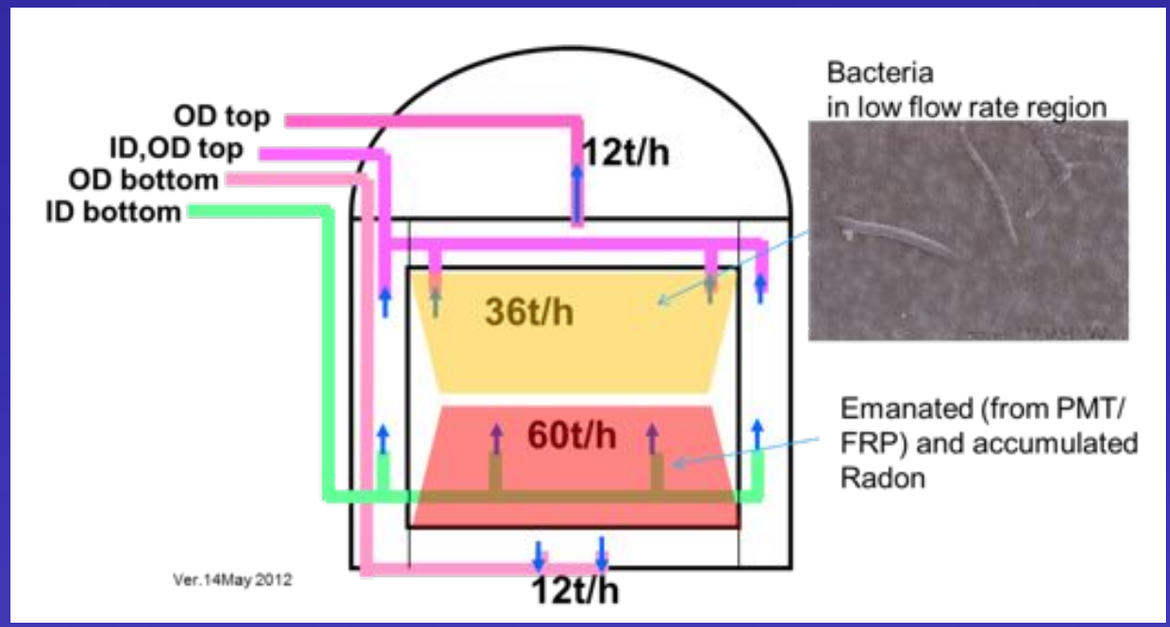


Housing

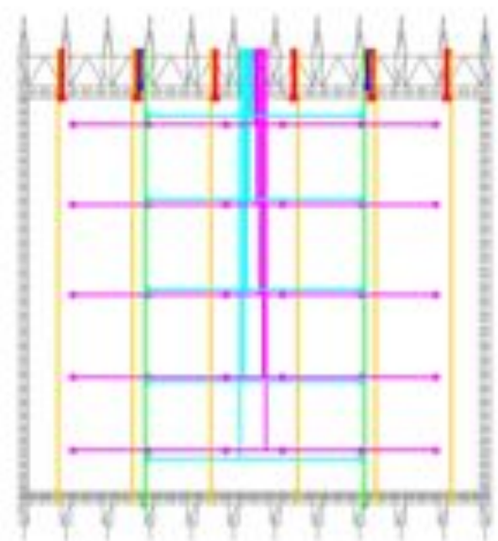


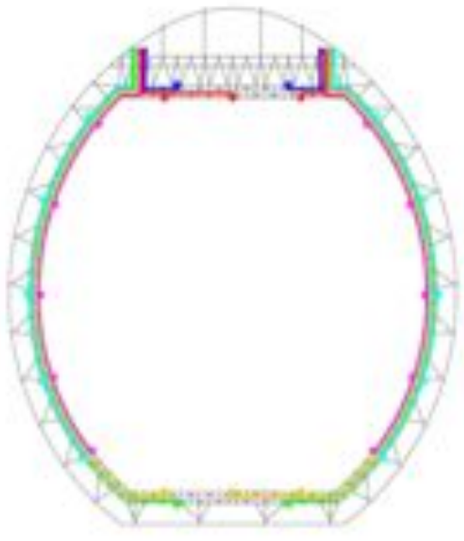
Water Quality Control and Purification system

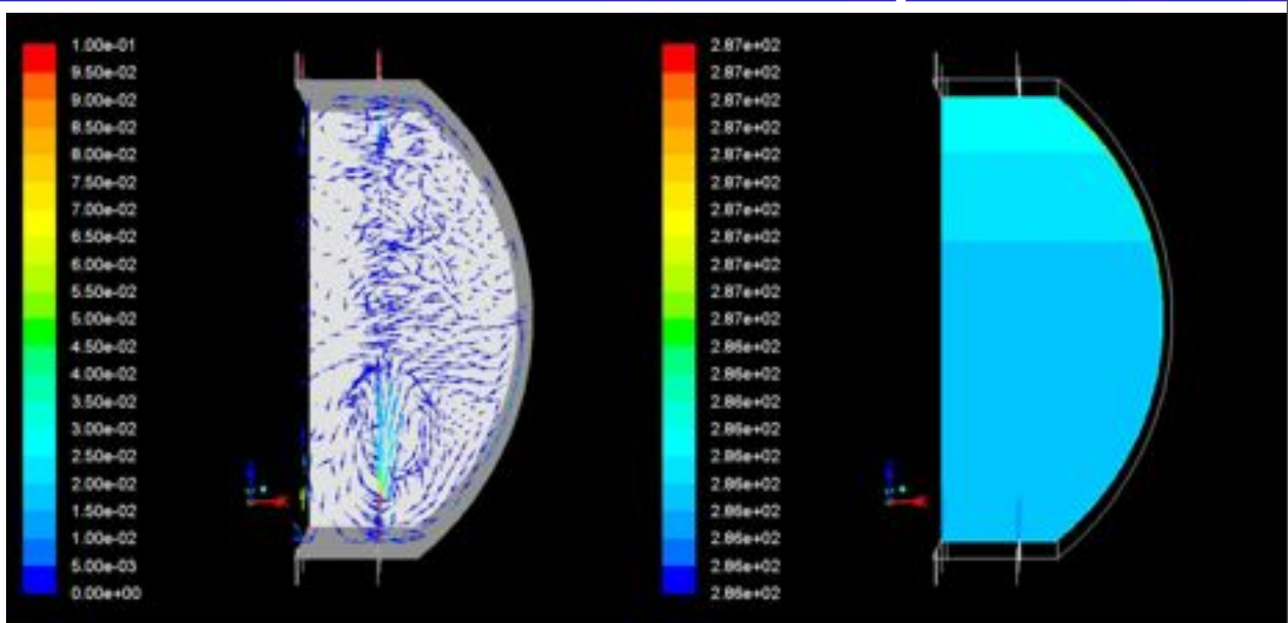
Water Simulation is under development



water flow temparature



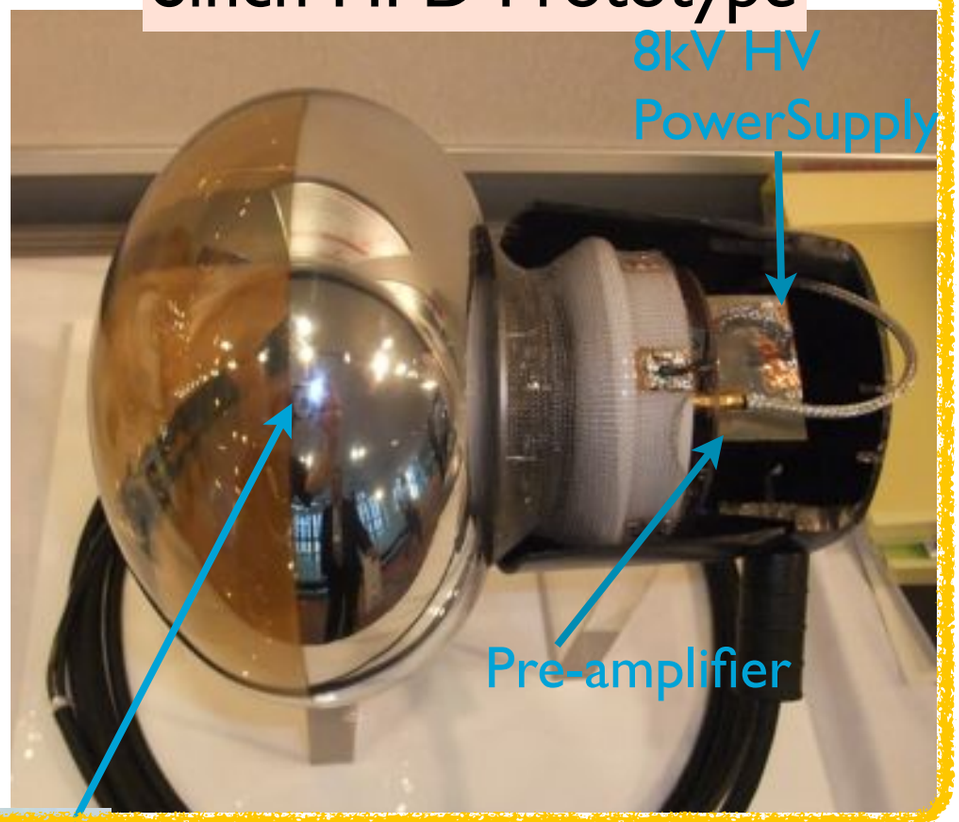




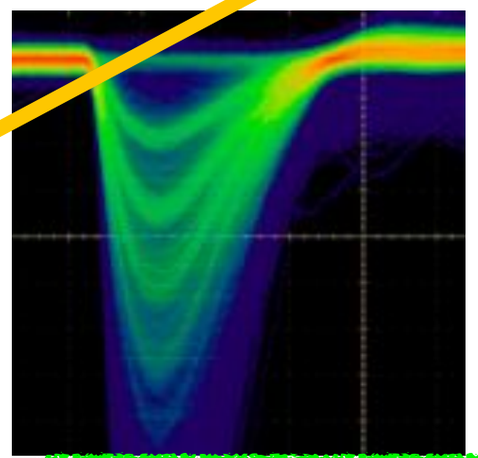
New PhotoSensor Development

- High QE 20' PMT (baseline)
- High QE 20' HPD (desired option)
  - Installing the new sensors in EGADS 200 ton tank for a long term test as a Water Cherenkov Detector

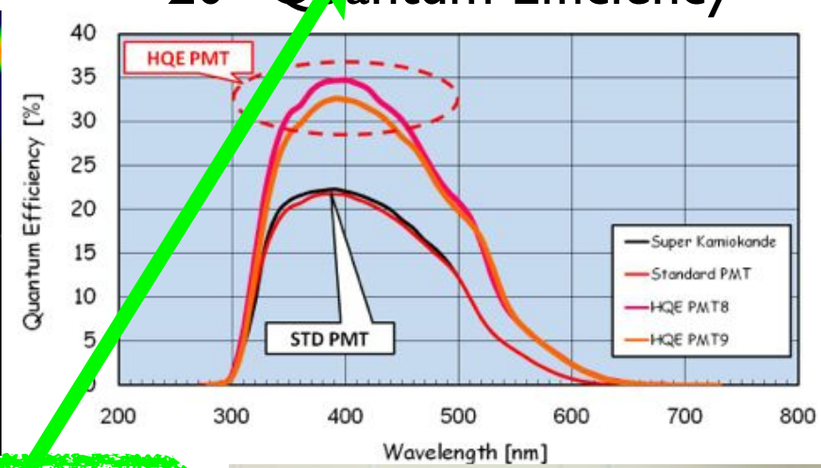
8inch HPD Prototype



5mmΦ Avalanche Detector



20" Quantum Efficiency



young physicists

Need more contributions to

- Electronics R&D and proto-type building
  - working in the water with reasonable cost
- DAQ R&D and proto-type building
- Software development
- Automated Calibration technique
- Verify all the system with a proto-type detector.

- These are the important inputs to the next stage document.
  - LOI (2011) → DONE
  - CDR (2013-2014)
  - TDR

History and Status of the project

- NOTE :
  - We do not have the system of CD1, CD2, ...CDX in Japan.
  - The government official approval is very serious. CD3 in US?
    - The project must be construed with the fixed term within the allocated budget w/o contingency.
  - Community consensus is very important and necessary.
  - R&D budget for Hyper-K is officially approved in July 2013.

Hyper-K in Japanese Future Strategy

- **Recommendation by HEP community**
  - http://www.jahep.org/office/doc/201202_hecsubc_report.pdf
  - Recommendations for two large-scale projects
    - Linear Collider
    - **Large-scale Neutrino & Nucleon decay Detector**
- **KEK roadmap includes Hyper-K**
  - http://kds.kek.jp/getFile.py/access?sessionId=1&resId=0&materialId=0&confId=11728
- **Cosmic Ray community endorses Hyper-K as a next large-scale project**
- **The master plan for large scale projects in Science Council of Japan**
  - A proposal of large neutrino/nucleon-decay detector is submitted with Hyper-K. J-PARC neutrino beam operation w ~>1MW and a near detector complex are also packaged. We expect the result by March 2014.
  - (Ref.) the master plan in 2010, Hyper-K was described in page 20
    - http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-21-t90-e2.pdf

- http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-21-t90-e2.pdf

Recommendation

Japanese Master Plan of Large Research Projects

—— A Table of 43 Selected Projects ——

17 March 2010

Science Council of Japan

Committee for Scientific Community

Subcommittee for Large Research Projects

A	Nucleon Decay and Neutrino Oscillation Experiments with Large Advanced Detectors	C : C 2

b)
This project builds up on the legacy of Super Kamiokande with a large number of international institutions.

A high priority will be considered by both particle and cosmic ray physics communities if the on-going long baseline neutrino (J-PARC to Kamioka T2K) experiment obtains the expected results.

A	Nucleon Decay and Neutrino Oscillation Experiments with Large Advanced Detectors	Construction : 50-75. Operation: 20 year.	Construction : 2014 to 2020. Operation: 2021 to 2035.	Advance neutrino physics/astronomy and search for nucleon decays using a large water Cherenkov detector that is approximately 20 times larger in volume than Super Kamiokande and/or a large liquid argon detector.	It would discover the particle-antiparticle asymmetry (CP asymmetry) in the lepton sector by shooting a muon neutrino beam from J-PARC to the advanced large neutrino detector. It will also probe the grand unified theories by searching for nucleon decays.	b) This project builds up on the legacy of Super Kamiokande with a large number of international institutions.	A high priority will be considered by both particle and cosmic ray physics communities if the on-going long baseline neutrino (J-PARC to Kamioka T2K) experiment obtains the expected results.

Japan HEP community

- http://www.jahep.org/office/doc/201202_hecsubc_report.pdf

Recommendations

The committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

- **Should a new particle such as a Higgs boson with a mass below approximately 1 TeV be confirmed at LHC, Japan should take the leadership role in an early realization of an e^+e^- linear collider.** In particular, if the particle is light, experiments at low collision energy should be started at the earliest possible time. In parallel, continuous studies on new physics should be pursued for both LHC and the upgraded LHC version. Should the energy scale of new particles/physics be higher, accelerator R&D should be strengthened in order to realize the necessary collision energy.

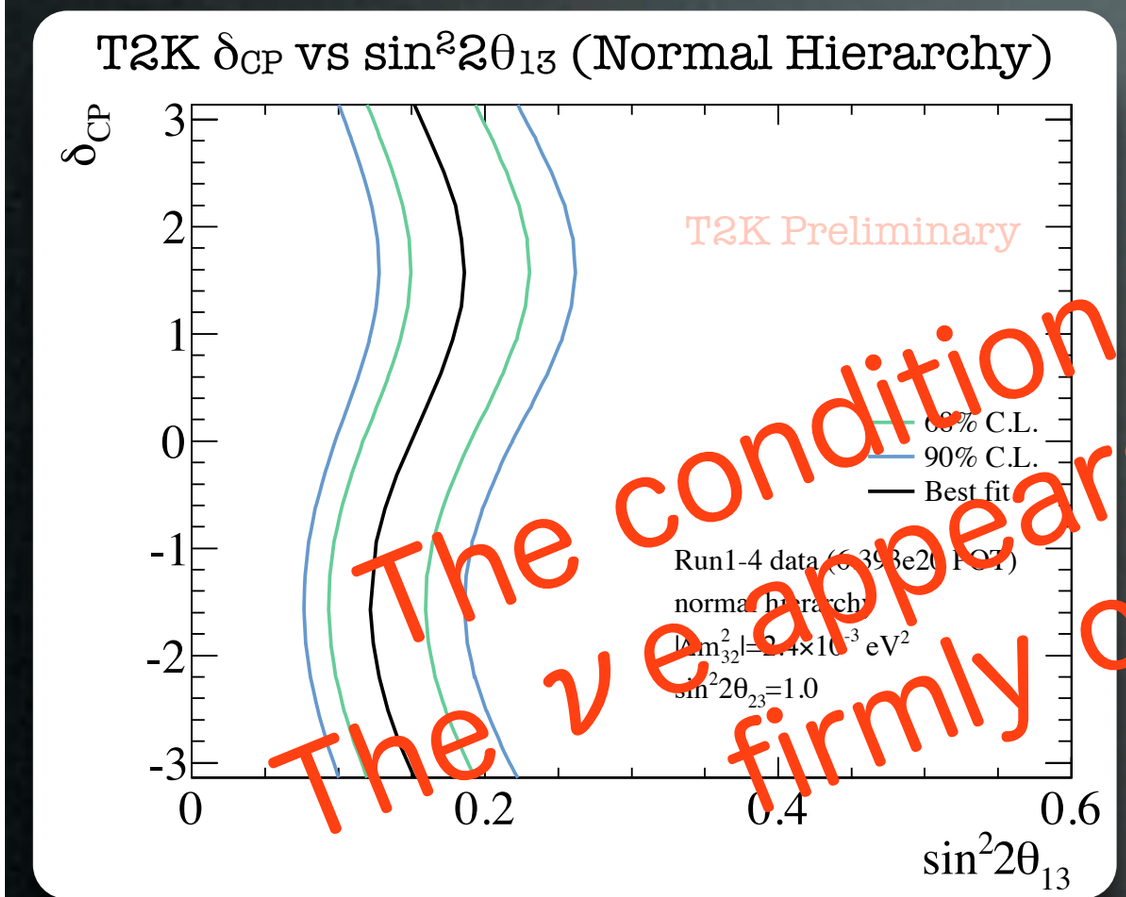
- **Should the neutrino mixing angle θ_{13} be confirmed as large, Japan should aim to realize a large-scale neutrino detector through international cooperation, accompanied by the necessary reinforcement of accelerator intensity, so allowing studies on CP symmetry through neutrino oscillations.** This new large-scale neutrino detector should have sufficient sensitivity to allow the search for proton decays, which would be direct evidence of Grand Unified Theories.

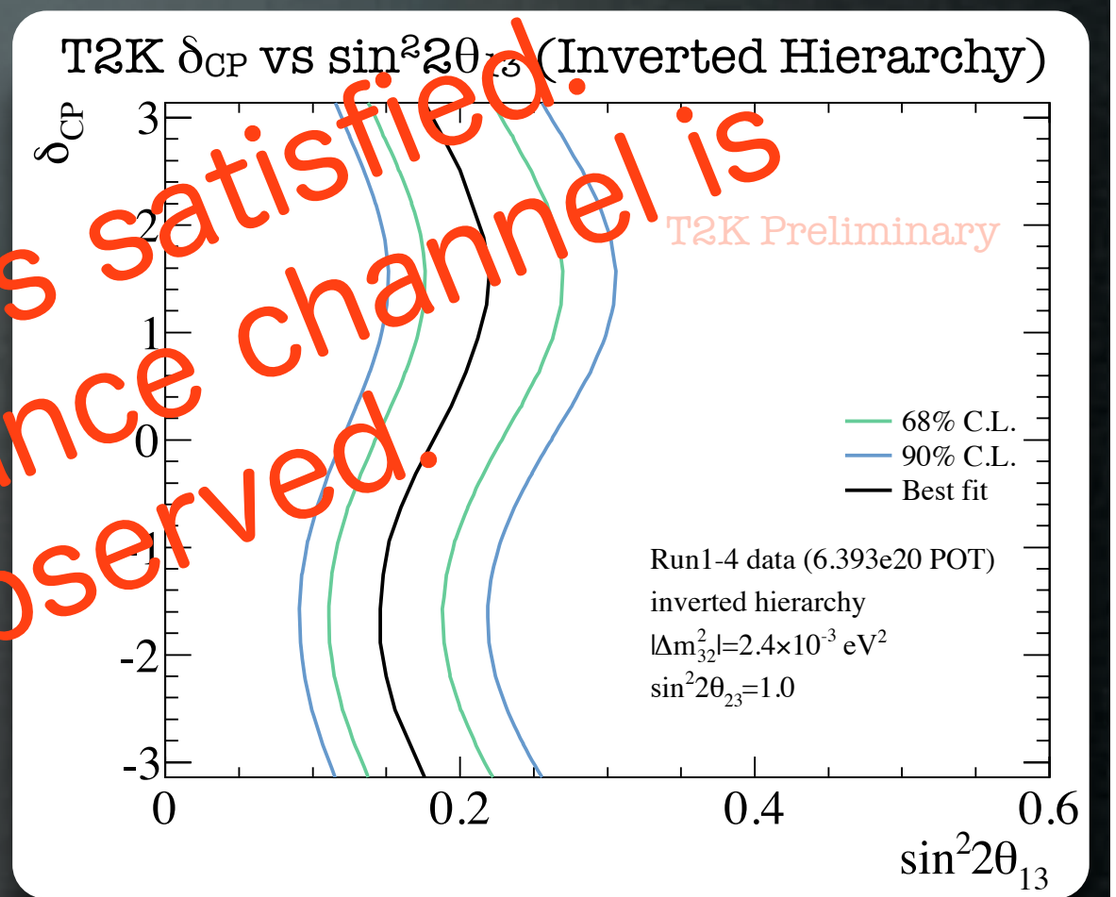
M. Wilking's T2K talk at EPS-HEP2013

ν_e Appearance Results

- **Observed 28 events** (expected 20.4 ± 1.8 for $\sin^2 2\theta_{13}$=0.1)
- Comparing the best p-θ fit likelihood to null hypothesis gives a **7.5σ significance for non-zero θ_{13}**

(For $\sin^2 2\theta_{23}$=1, δ_{CP}=0, and normal mass hierarchy)





The condition is satisfied.
The ν e appearance channel is firmly observed.

First ever observation (>5σ) of an explicit ν appearance channel

Timelines of Current/Future Projects

Hyper-K Working Group Organization

- oversee the HK group
- channel for contacting to the group
- involve non-Japanese in future

More leading physicists are welcome from the international community

Steering Committee
Nakaya (chair)
Aihara, Nakahata,
Shiozawa, Yokoyama
+ a few more

Project Leader
Shiozawa

- PL oversees the sub-WGs
- WG conveners may be composed of one Japanese plus some non-Japanese.

WG1
Shiozawa

WG2
Sekiya,
Vagins

WG3
Nakayama,
Nishimura

WG4
Hayato

WG5
Miura
Walter

WG6
HideTanaka,
HiroTanaka,
Koshio,Mine,
Mccauley

WG7
Convener
Hartz

Physics WG conveners
Yokoyama

Phys-WG1
Yokoyama

Phys-WG2
Wendell

Phys-WG3
Takeuchi

WG1: Cavity and Tank
WG2: Water
WG3: Photo-sensor
WG4: DAQ
WG5: Software
WG6: Calibration
WG7: Accelerator&Near Detectors

Phys-WG1: Accelerator
Phys-WG2: Atmν+Nucleon decays
Phys-WG3: Astroparticle Physics (SN, solarν, etc)

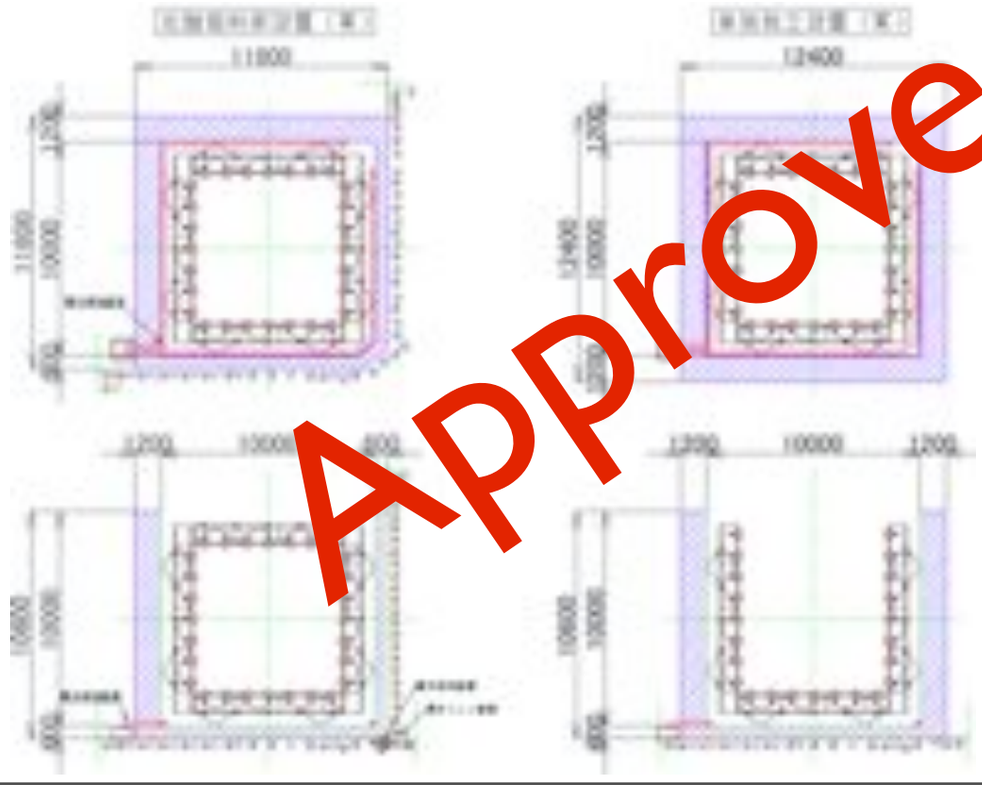
Budget request for the Hyper-K prototype w/ several R&D subjects

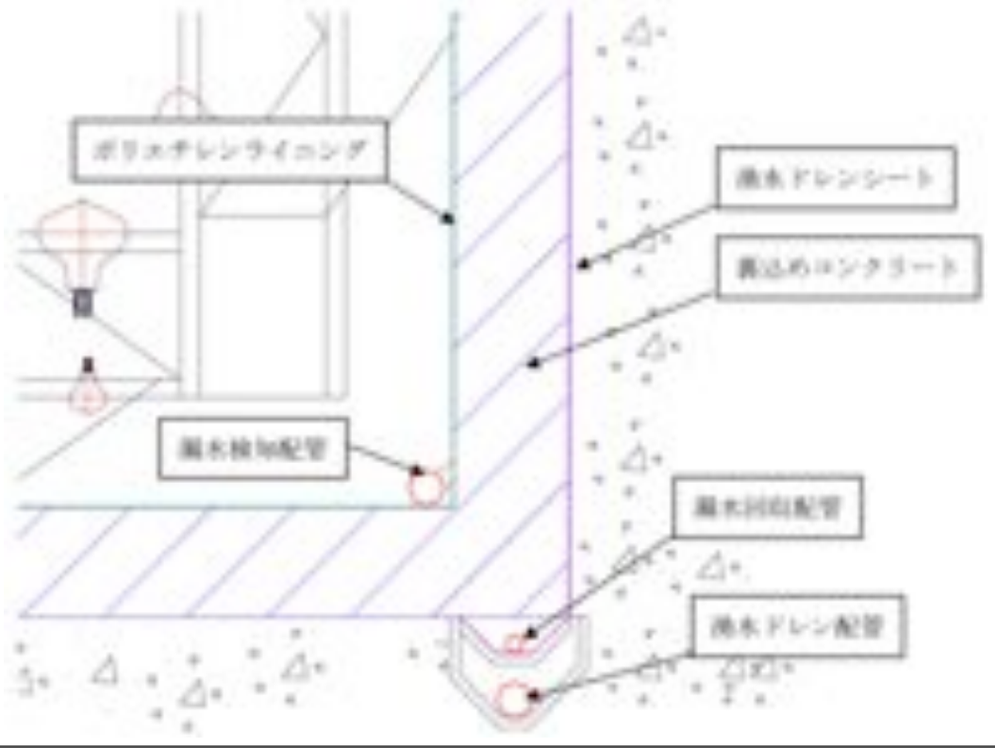
- Submitted a proposal of R&D to Grant-in-Aid ($2.3M/5year). **→$1.7M/5 year**

- Prototypical Detector
  - ~1kton (10x10x10m^3)
  - Feasibility test of
    - Liners
    - Leak water collection (drain), detection
    - photo-sensor support structure
    - DAQ system
    - Calibration system
- Including development of Water system, Photo-sensor, Electronics, Calibration system, Software ...

July 2013

Approved in July

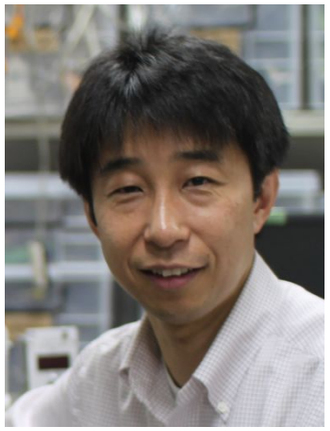




【Grant - in - Aid for Scientific Research on Innovative Areas(Research in a proposed research area)】

20 proposals are selected every year in all science area

Science and Engineering



Title of Project : Unification and Development of the Neutrino Science Frontier

Tsuyoshi Nakaya (Kyoto University, Graduate School of Science, Professor)

Approved in July 2013

【Content of the Research Project】

This project will advance experiments to study the properties of neutrinos, observe neutrinos in nature, develop new technologies for particle physics experiments, and promote theoretical studies in neutrino field. We have the following research projects. (a) Measurement of neutrino oscillation using a neutrino beam from the J-PARC accelerator to the Super-Kamiokande detector (Fig. 1). (b) Measurement of neutrino oscillation by observation of reactor neutrinos and further application of the techniques to reactor monitoring technology. (c) Observation of atmospheric neutrinos. R&D of the next generation nucleon-decay and neutrino detector "Hyper-Kamiokande" is promoted. (d) Investigation of deep space by observation of ultra-high-energy cosmic neutrinos. We will

【Term of Project】 FY2013-2017

【Budget Allocation】 1,116,100 Thousand Yen

Budget: $11.16 M

Term: 2013-2017

Main items:

- T2K/J-PARC (~$1.8M)
- Reactor ν (~$2.1M)
- Hyper-K (~$1.7M)
- Ice-Cube (~$1.4M)
- other basic ν R&D

NOTE:
Neutrino-less double β decay experiments (KamLAND-Zen) is not included because it is already supported by another Grant-i-Aud

Neutrino Physics

- Needless to say, we are in the very exiting years in neutrino physics
  - The first evidence of $\nu_\mu \rightarrow \nu_e$ by T2K in 2011 which is the key channel to study CPV and MH of neutrinos.
  - Precise measurements of θ_{13} support the evidence by reactor experiments (Daya-Bay, D-Chooz, RENO) in 2012.
  - **Firm Observation of $\nu_\mu \rightarrow \nu_e$ by T2K in 2013**
- Strong near term experiments
  - T2K: may have a hint on CPV w/ the precise reactor θ_{13} measurements (and an anti-neutrino beam) within several years.
  - NOνA: may have a first evidence of MH and a hint on CPV together with T2K and reactors.
- Excellent global future projects
  - Hyper-K (including J-PARC ν beam)
  - LBNE
  - LBNO/LAGUNA

Messages to our colleagues in Snowmass

- Very Important to work together for future neutrino projects.
  - (T2K, NOvA), LBNE, Hyper-K, LBNO/LAGUNA
    - Need to develop
      - High Power accelerators
      - High Power and High Quality ν beam
      - Advanced Detector Technology
      - Physics developments (Hadron production, Neutrino Cross Sections, Global oscillation parameter constraint)
- Let's support each other in cooperation for the same goal.
  - **Explore the mystery of Neutrinos**
  - The Hyper-K group is seeking more contributions (and more man powers) to complete R&D and Technical Design on time w/ a proto-type detector construction.

NNN13 workshop

Nov.11-13, 2013

wpi World Premier International Research Center Initiative

東京大学 THE UNIVERSITY OF TOKYO

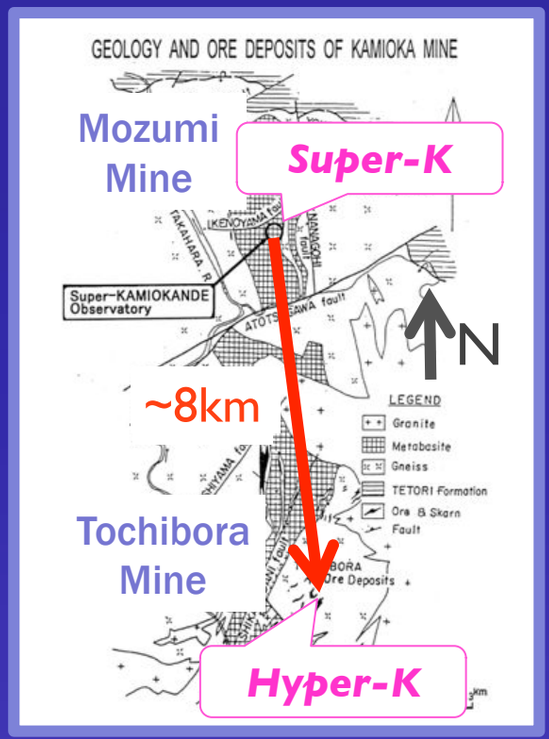
TODIAS 東京大学国際高等研究所 TODAI INSTITUTES FOR ADVANCED STUDY

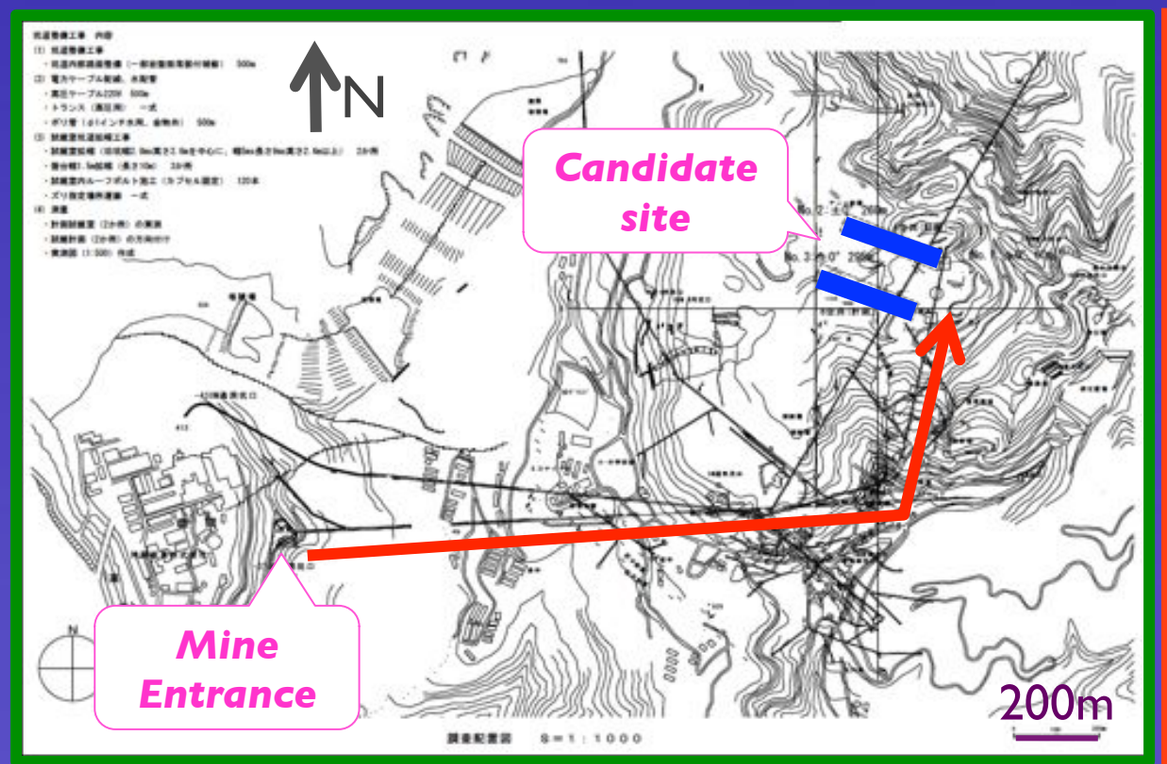
THE KAVLI FOUNDATION

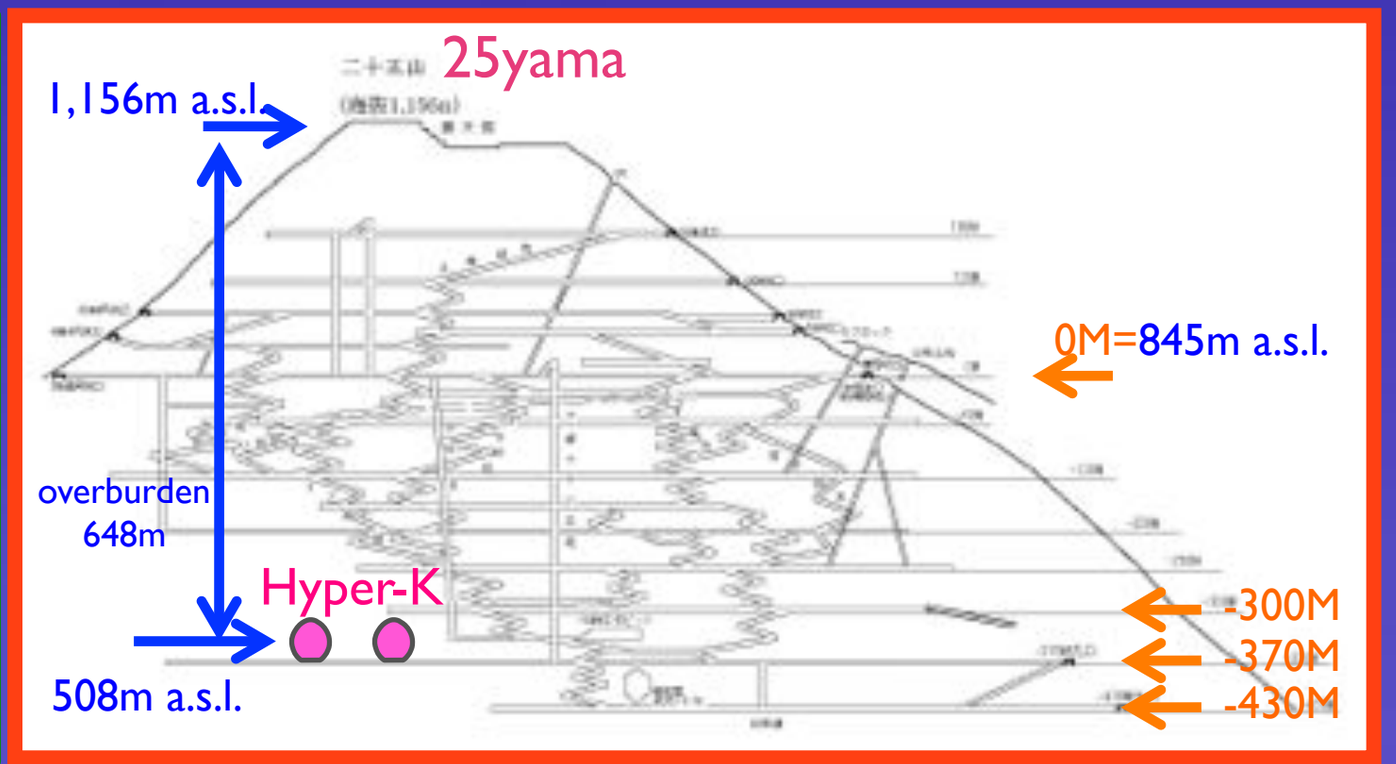
Backup

Hyper-K candidate site

- 8km south from Super-K
  - same T2K beam off-axis angle (2.5 degree)
  - same baseline length (295km)
- 2.6km horizontal drive from entrance
- under the peak of Nijuugo-yama
  - 648m of rock or 1,750 m.w.e. overburden
- 13,000 m^3/day or 1megaton/80days natural water







Overview of the geological survey

Tunnel

Bore hall core

-300mL (~tank top)

-370mL (tank floor)

-430mL

No.4 hole(-370mL)

epidote

Namari

epidote inclusive

Yurume Fau

-370mL Shin-2ban-mukae Tunnel

-430mL Kita-mukae Tunnel

No.5 hole(-370mL)

Anko Fault

Yurume Fault

Rock Classification

A

B

CH

CM

CL

D

sheared zone

20cm or less

20～50cm

50cm or more

CM class or lower area

No.2hole (-370mL)

-300mL Survey Borehole

North-side Cavern

South-side Cavern

No.3 hole (-370mL)

240° Fault

240° Fault

240° Fault

Anko Fault

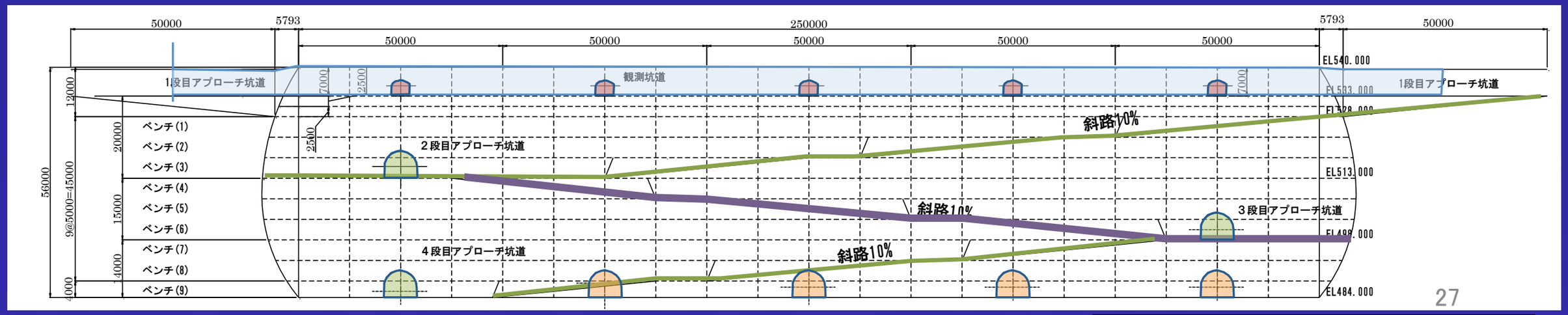
Scope of Rock mass Classification Surveyed :

-370mL Moribuden Mukae Tunnel

magnetite inclusive

-300mL Kita Mukae Tunnel

Cavern analysis



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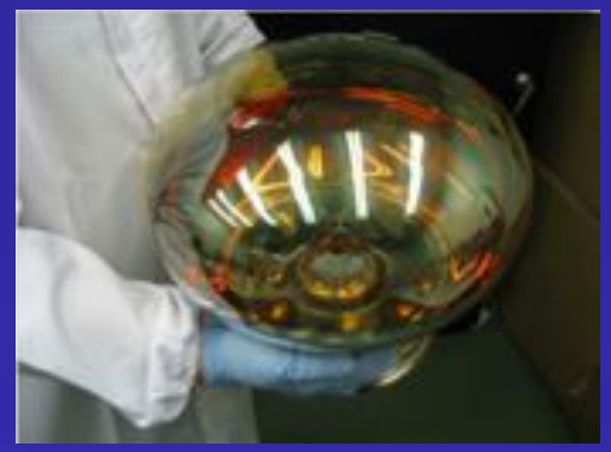
step-by-step calculations for each excavation benches

- cavity analysis (and PS anchor design) going on
- scheduling & costing ongoing

Photo-sensor

- Candidates for ID sensor
  - 20” Hybrid Photo Detector (HPD)
  - (New 20” PMT as backup)
- Proof test of 8” HPD in a water tank from this winter
- 20” HPD prototype is expected in ~a half year



Preparation @ Kamioka

CP measurement with J-PARC ν and Hyper-K

- Strength of water Cherenkov detector
  - LARGE mass – statistics is always critical
  - Excellent reconstruction/PID performance especially in sub-GeV region (quasi-elastic→single ring)
- Best matched with low energy, narrow band beam
  - Off-axis beam with relatively short baseline
    - Less matter effect
    - Complementary to other > ~1000km baseline experiments planned w/ Lq.Ar

(natural extension of technique proved by T2K)

純水製造・循環システム開発

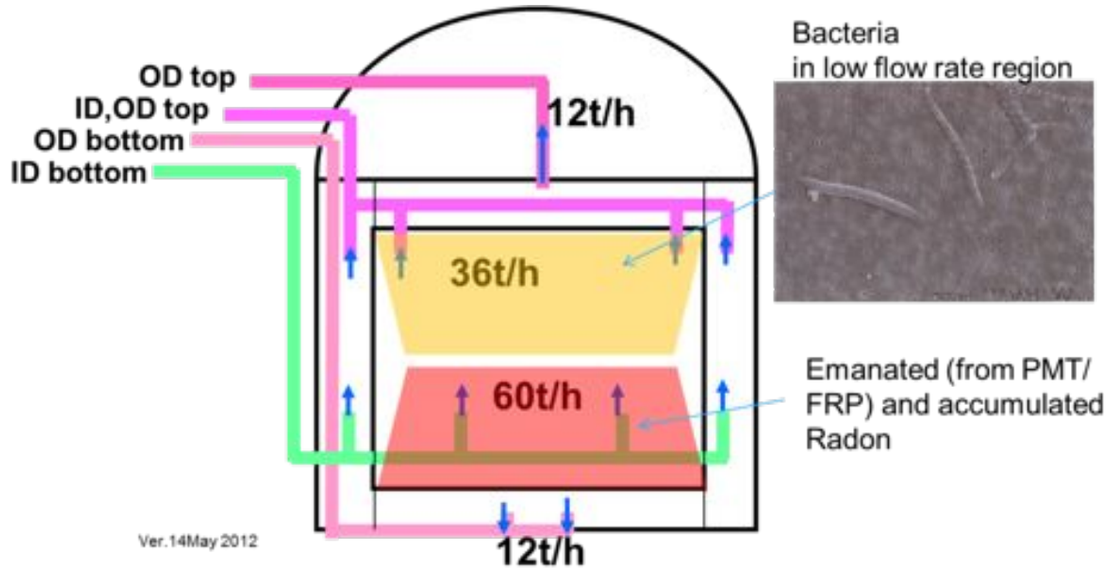
1、HK水槽内の水流、配管設計

SKでの問題

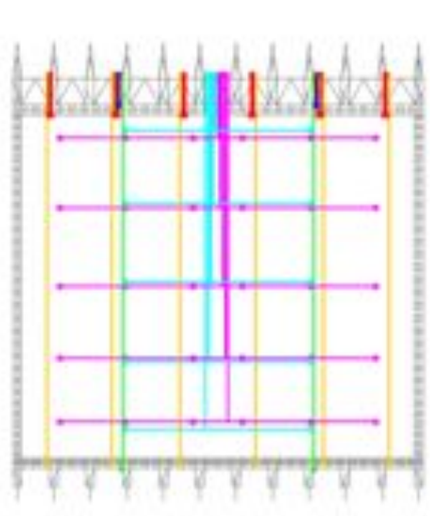
水の流れを考慮せず設計された

→上部の水は滞留、下部の水は対流

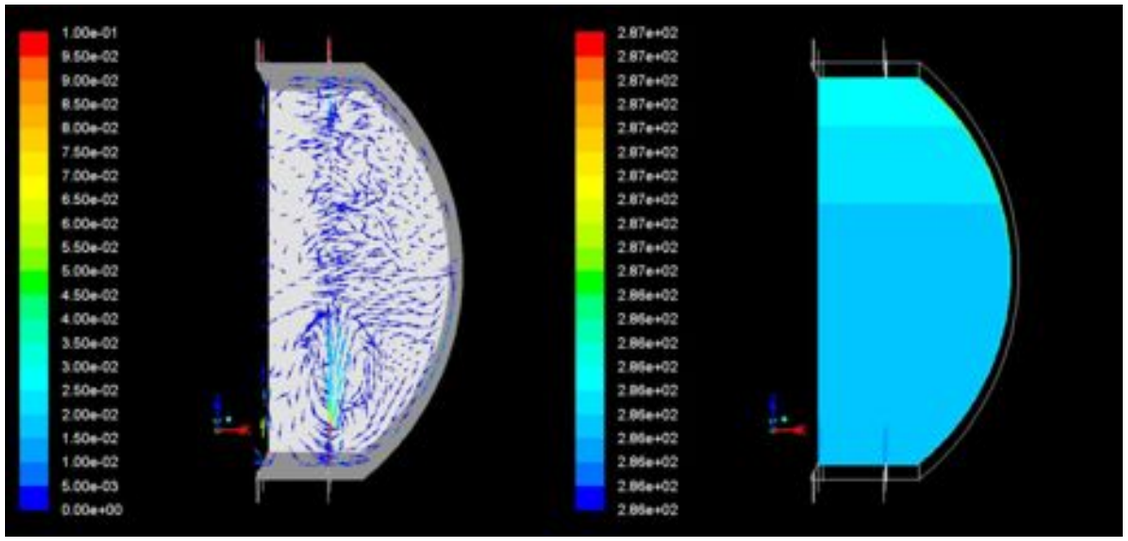
→透過率やバックグラウンド悪化の原因となり物理解析に対する制限となっている。



1－1、シミュレーションによる配管設計



流れベクトル　　温度分布



1－2、SK、HKプロトタイプ検出器による試験

2、コスト削減のための設計変更、試験

設計のベースはSK。adhocに改良を重ねて来ているため、HKに対してはオーバースペックの可能性。 SK、HKプロトタイプ検出器による試験を行う。

Let's realize the Detector

- The next open Hyper-K meeting will be on June 21-22, 2013 in Japan.
- All you are WELCOME!